MEASUREMENT AND VERIFICATION PLAN

FOR

DG/CHP SYSTEM AT VBC INDUSTRIES
156 SANFORD STREET BROOKLYN, NY 11205

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Submitted to:

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1. Introduction

VBC Industries is an injection molding facility located in Brooklyn, NY. The CHP system at VBC Industries includes twelve (12) 100-kW CM-100 inverter based engine generator units from Tecogen. The engines are capable of providing 125 kW peak and 100 kW continuous output. The inverters, oil coolers, and associated electronics for each engine have their own small cooling loop and dry cooler (IC/EC-1 – IC/EC-12). A heat rejection loop from the engine jacket and exhaust heat exchanger is the primary source of thermal output.

The engine generators are electrically separated into two banks of five, with each bank dedicated to individual utility services at the facility (Figure 1). The remaining two engine generators are “swing” units, with interconnection capabilities on either utility service. “Gross” electrical output from the CHP system are metered at the collector bus for each group of generators (DMD-2, DMD-4). A parasitic load panel (MCC-CHP) can be fed from either electrical service, and coupled with either group of generators, but the parasitic panel connection is not captured by either generator power transducer.

Heat from the engine generator jacket water and exhaust is recovered in the form of 230^{0}F hot water. Heat recovery piping for the engine generators is piped in a primary/secondary piping arrangement, with the generators grouped in two groups of six. Each group of six generators is piped on its own primary loop, and each generator has its own primary circulation pump (CGP-1 – CGP-12). Each primary loop has a dump radiator (FLC-1, FLC-2), which is isolated from the primary loop by a heat exchanger. The two primary loops connect to the secondary hot water loop via a bridge piping connection.

The secondary hot water loop uses two variable speed pumps (HWP-13/14) to match the flow to the requirements of the two thermal loads on the system. The hot water from the engines is used to meet a 350-ton single effect (0.75 COP) absorption chiller (ABS-1) requiring 6.0 MMBtu/h input.

This document represents the **minimum requirements** to perform the two (2) year M&V period for this performance CHP project.

1. Monitoring Points

The ALC control system at the site will be used for data collection. Table 1 lists the monitored points that will be used to characterize the performance of the CHP system. Sensor type, the expected engineering units, and the CDH point name (will be used in the data analysis section) are also shown in the table (where available). Locations of the sensors in the design identified as critical for monitoring the CHP performance are shown in Figure 1 through Figure 5.

Table 1. List of Monitored Data Points to be Collected

No.	Drawing Tag Name	Report File Column Label	Manufacturer/ Model #	Description	CDH Point Name	Eng Units
1	DMD-1	Utility-A KW In	Square D Powerlogic circuit monitor	Total Facility Utility Service #1 Power/Energy	WT1	kW/kWh
2	DMD-3	Utility B KW In	Square D Powerlogic circuit monitor	Total Facility Utility Service #1 Power/Energy	WT2	kW/kWh
3	DMD-2	CHP-1 KW Out	Eaton IQ 250/260	CHP Power Group #1 Output	WG1	kW/kWh
4	DMD-4	CHP-2 KW Out	Eaton IQ 250/260	CHP Power Group #2 Output	WG2	kW/kWh
5	DMD-5	MCC-CHP KW	TBD	MCC-CHP Power/Energy	WPAR	kW/kWh
6	TS-21	SL Supply Temp	RTD	Secondary Loop Supply Temp.	TSLS	deg F
7	N/A	SL CH-HWR Temp	RTD	Secondary Loop Return Temp After Chiller	TSLR1	deg F
8	FM-3	SL Flow	Onicon F-1210	Secondary Loop Flow Rate	FSL	GPM
9	TS-13	PL1 HX EWT	RTD	Primary Loop #1 Temperature Entering Dump HX	TPL1R1	deg F
10	TS-14	PL1 HX LWT	RTD	Primary Loop #1 Temperature Leaving Dump HX	TPL1R2	deg F
11	TS-37	PL1 Supply Temp	RTD	Primary Loop #1 Supply Temperature	TPL1S	deg F
12	FM-2	PL1 Flow	Onicon F-1210	Primary Loop #1 Flow	FPL1	GPM
13	TS-17	PL2 HX EWT	RTD	Primary Loop #2 Temperature Entering Dump HX	TPL2R1	deg F
14	TS-18	PL2 HX LWT	RTD	Primary Loop #2 Temperature Leaving Dump HX	TPL2R2	deg F
15	TS-3	PL2 Supply Temp	RTD	Primary Loop #2 Supply Temperature	TPL2S	deg F
16	FM-1	PL2 Flow	Onicon F-1210	Primary Loop #2 Flow	FPL2	GPM
17	GM-1	CHP Gas Flow	Onicon F-5500	CHP System Gas Flow	FG	CF/CFH
18	N/A	Tecogen-1 KW	Tecogen Modbus	Generator #1 Gross Power	WG1	kW
19	N/A	Tecogen-2 KW	Tecogen Modbus	Generator #2 Gross Power	WG2	kW
20	N/A	Tecogen-3 KW	Tecogen Modbus	Generator #3 Gross Power	WG3	kW
21	N/A	Tecogen-4 KW	Tecogen Modbus	Generator #4 Gross Power	WG4	kW
22	N/A	Tecogen-5 KW	Tecogen Modbus	Generator #5 Gross Power	WG5	kW
23	N/A	Tecogen-6 KW	Tecogen Modbus	Generator #6 Gross Power	WG6	kW
24	N/A	Tecogen-7 KW	Tecogen Modbus	Generator #7 Gross Power	WG7	kW
25	N/A	Tecogen-8 KW	Tecogen Modbus	Generator #8 Gross Power	WG8	kW
26	N/A	Tecogen-9 KW	Tecogen Modbus	Generator #9 Gross Power	WG9	kW
27	N/A	Tecogen-10 KW	Tecogen Modbus	Generator #10 Gross Power	WG10	kW
28	N/A	Tecogen-11 KW	Tecogen Modbus	Generator #11 Gross Power	WG11	kW
29	N/A	Tecogen-12 KW	Tecogen Modbus	Generator #12 Gross Power	WG12	kW

Sensors in yellow indicate readings not reporting as of 3/31/2017.

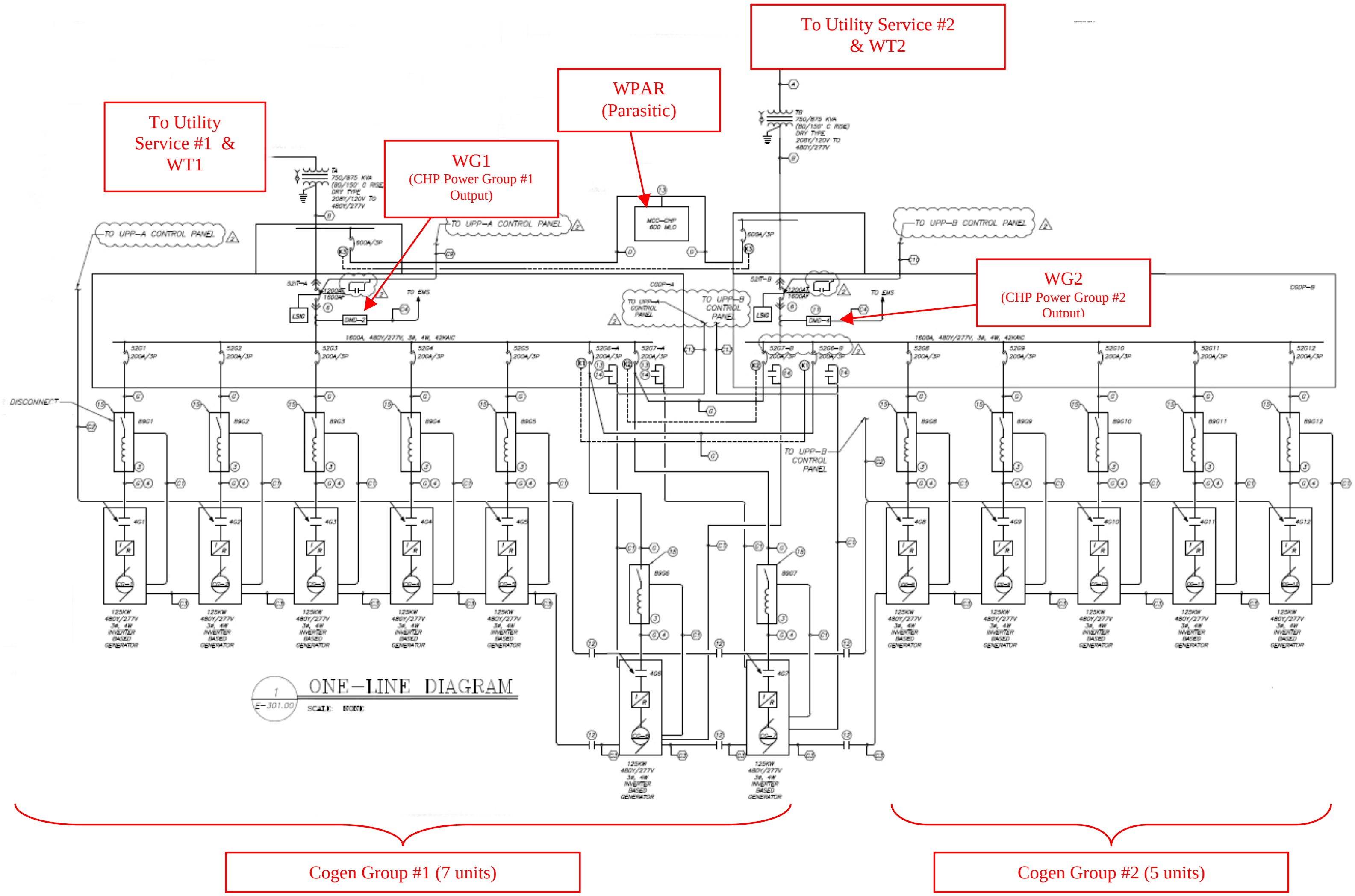

Figure 1. Partial Electrical One Line Diagram (From Drawing E-301.00)

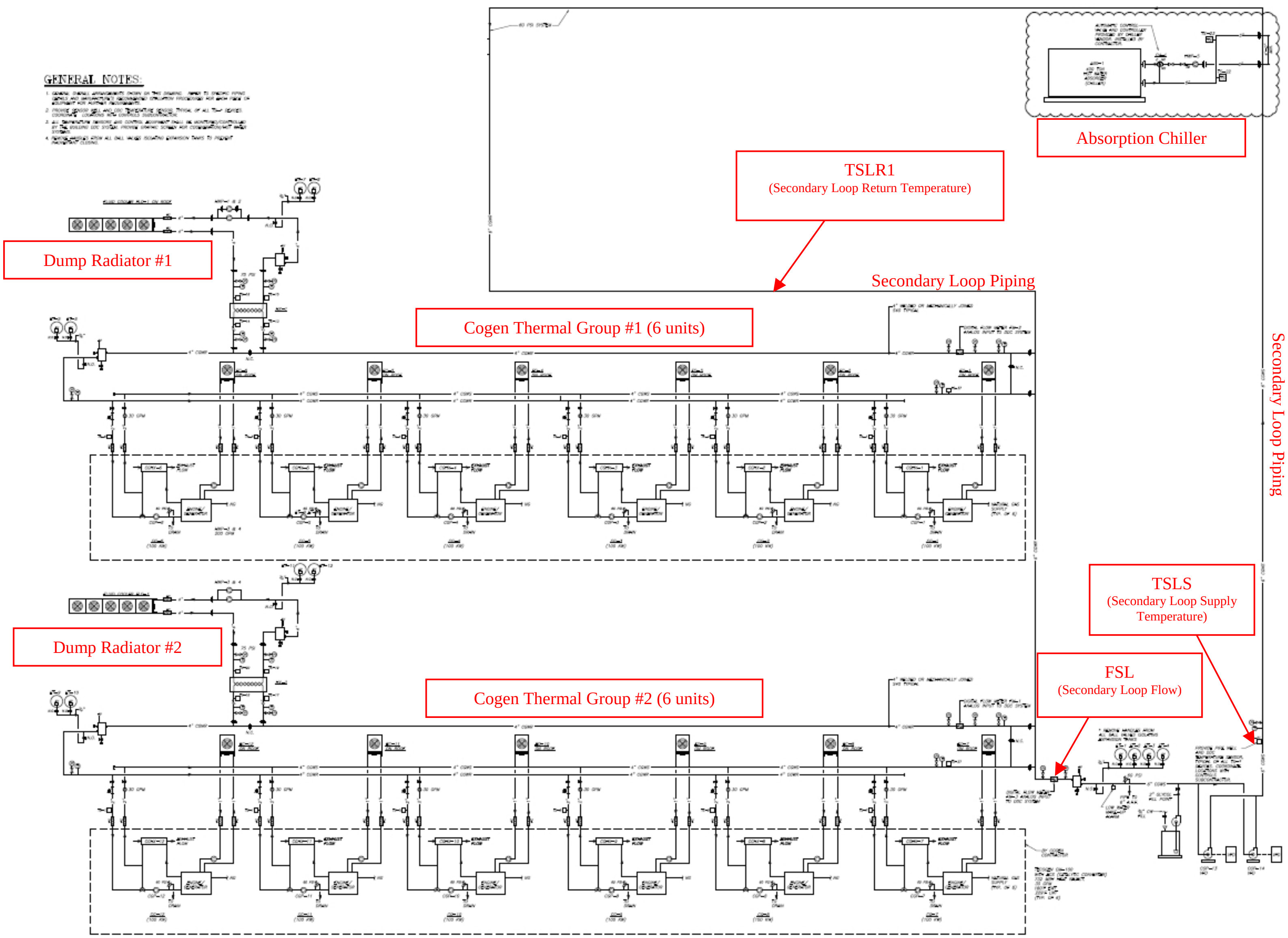

Figure 2. System Piping Diagram (From Drawing M-301.00)

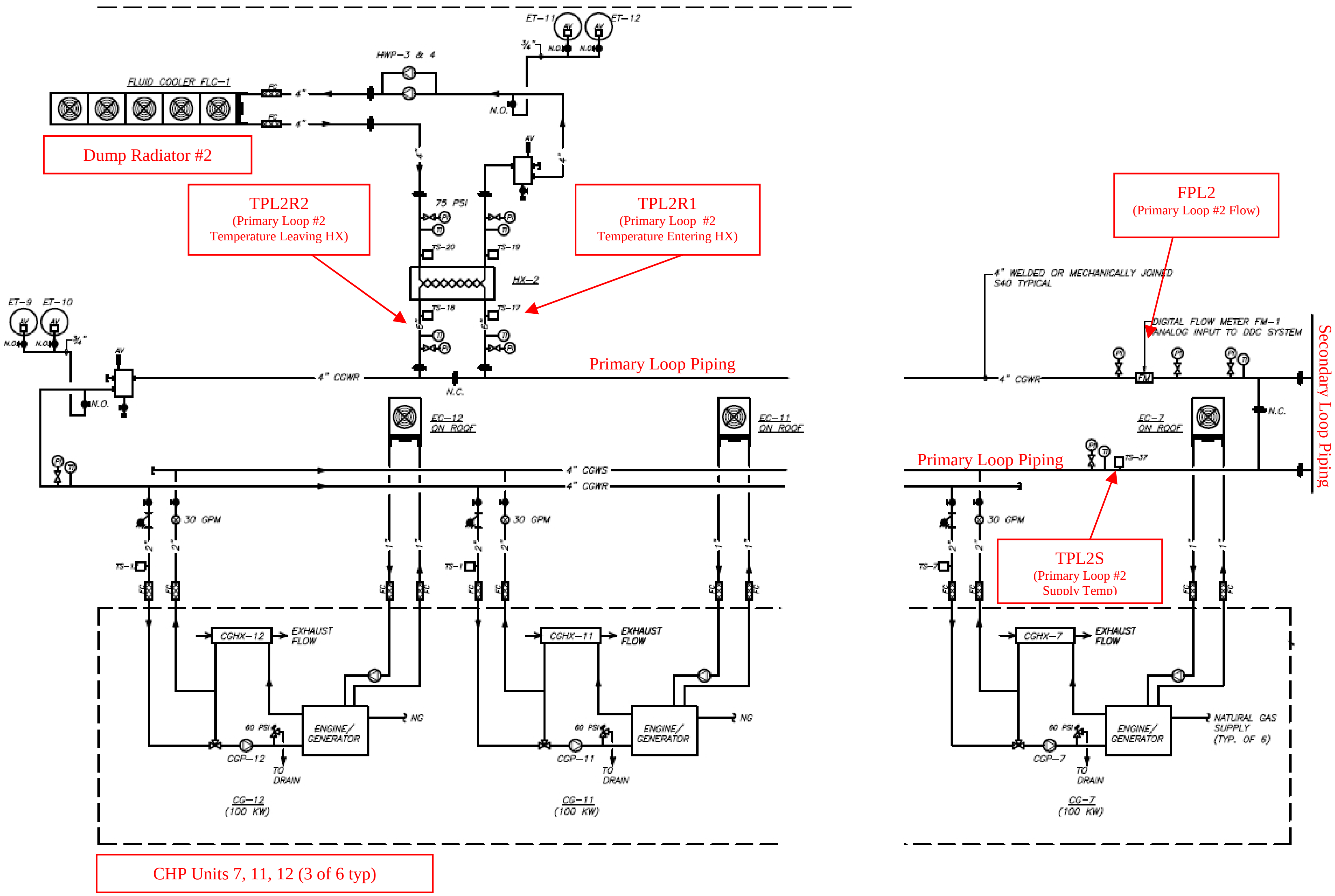

Figure 3. Cogen Thermal Group #2 Piping Diagram (From Drawing M-301.00)

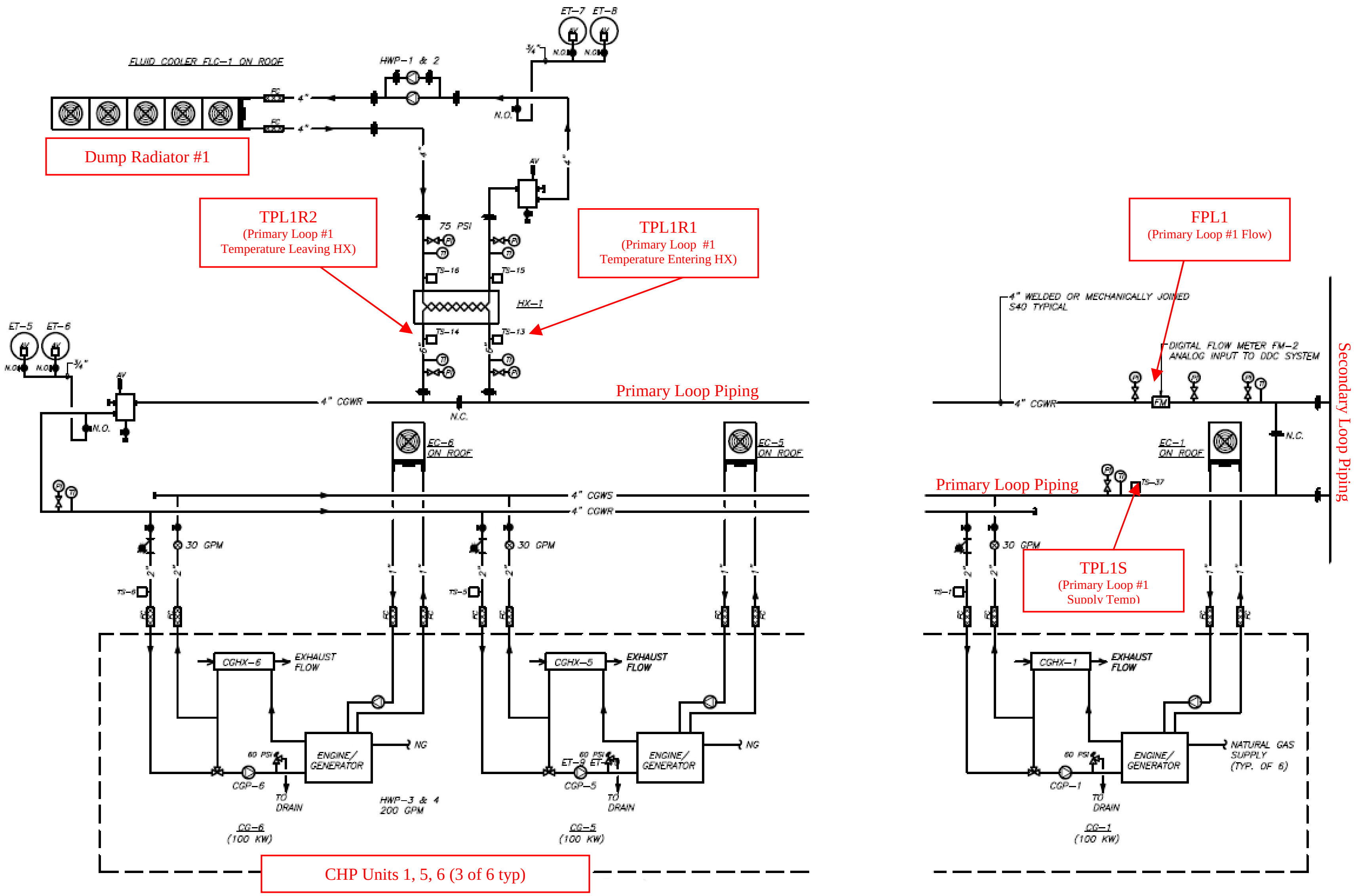

Figure 4. Cogen Thermal Group #1 Piping Diagram (From Drawing M-301.00)

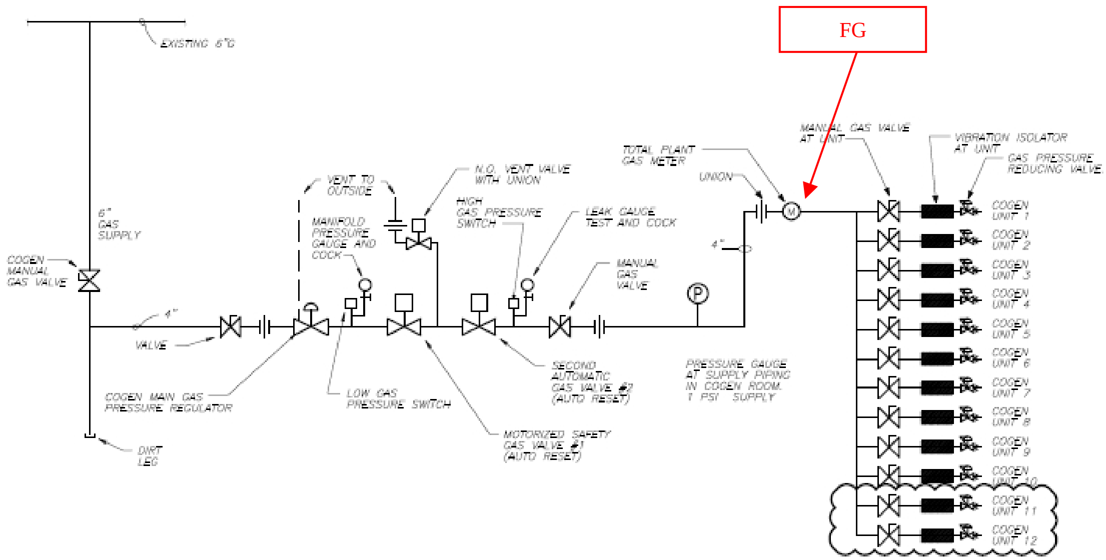

Figure 5. Cogen Gas Piping Diagram (From Drawing M-501.00)

Data Logging Equipment

The ALC control system will be used transfer 15-minute data to CDH each night by email from bms@vbcpkg.com to data_collection@cdhenergy.com. The ALC system emails the data listed in Table 1 as a time-stamped CSV file. The file contains one day of data, consisting of 96 15-minute records, and uses a filename convention of "M&V YYYY MMM DD HHMM.csv" (e.g. M&V 2017 Mar 31 0700.csv for March 31, 2017).

Verification

Once the data collection process is established and all meters are reporting, CDH Energy staff will come on-site and use our hand held meters to confirm proper readings are being collected.

2. Data Analysis

Heat Recovery

The amount of useful heat recovery for this system will be calculated using the sum of the heat transfer on the primary loops. The instrumentation on the primary loops allows for calculation of the useful and rejected heat recovery from each thermal group.

Useful heat recovery	QU	=	K·FPL1·(TPL1S-TPLlR1) + K·FPL2·(TPL2S-TPL2R1)	(primary loops)
Rejected heat recovery	QR	=	K·FPL1·(TPL1R1-TPLlR2) + K·FPL2·(TPL2R1-TPL2R2)	(primary loops)

The factor K will be determined based on the fluid in the loops, which is expected to be a glycol-water mix (K is approximately 0.480 for 30% glycol).

Electrical Output

For this site, the gross power output from the engine generators will be measured by the power transducer in the CGDP-A and CGDP-B panels, requiring the parasitic power to be subtracted off to produce net CHP output.

Net Electrical Output	Wnet	=	WG1 + WG2 - WPAR

Calculated Quantities

The fuel conversion efficiency of the CHP system, based on the lower heating value of the fuel, will be defined as:

$$FCE = \frac{QU \cdot \Delta t + 3.412 \cdot (Wnet)}{LHV_{gas} \cdot FG}$$

where:	QU	-	Useful heat recovery (MBtu/h)
	Wnet	-	Generator output (kWh)
	FG	-	Generator gas consumption (Std CF)
	Δt	-	0.25 hour for 15-minute data
	LHV_{gas}	-	Lower heating value for natural gas (0.9 × HHV 1.030 MBtu/CF)